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Keyhole Reservoir
Crook County, Wyoming

National Eutrophication Survey, Corvallis, Oreg

Aug 77

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U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT

ON

KEYHOLE RESERVOIR

CROOK COUNTY

WYOMING

EPA REGION VIII

WORKING PAPER No. 888

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON

and

ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

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REPORT
ON
KEYHOLE RESERVOIR
CROOK COUNTY
WYOMING
EPA REGION VIII
WORKING PAPER No. 888

WITH THE COOPERATION OF THE
WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
AND THE
WYOMING NATIONAL GUARD
AUGUST, 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Wyoming Department of Environmental Quality for professional involvement, to the Wyoming National Guard for conducting the tributary sampling phase of the Survey, and to those Wyoming wastewater treatment plant operators who voluntarily provided effluent samples.

The staff of the Water Quality Division provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

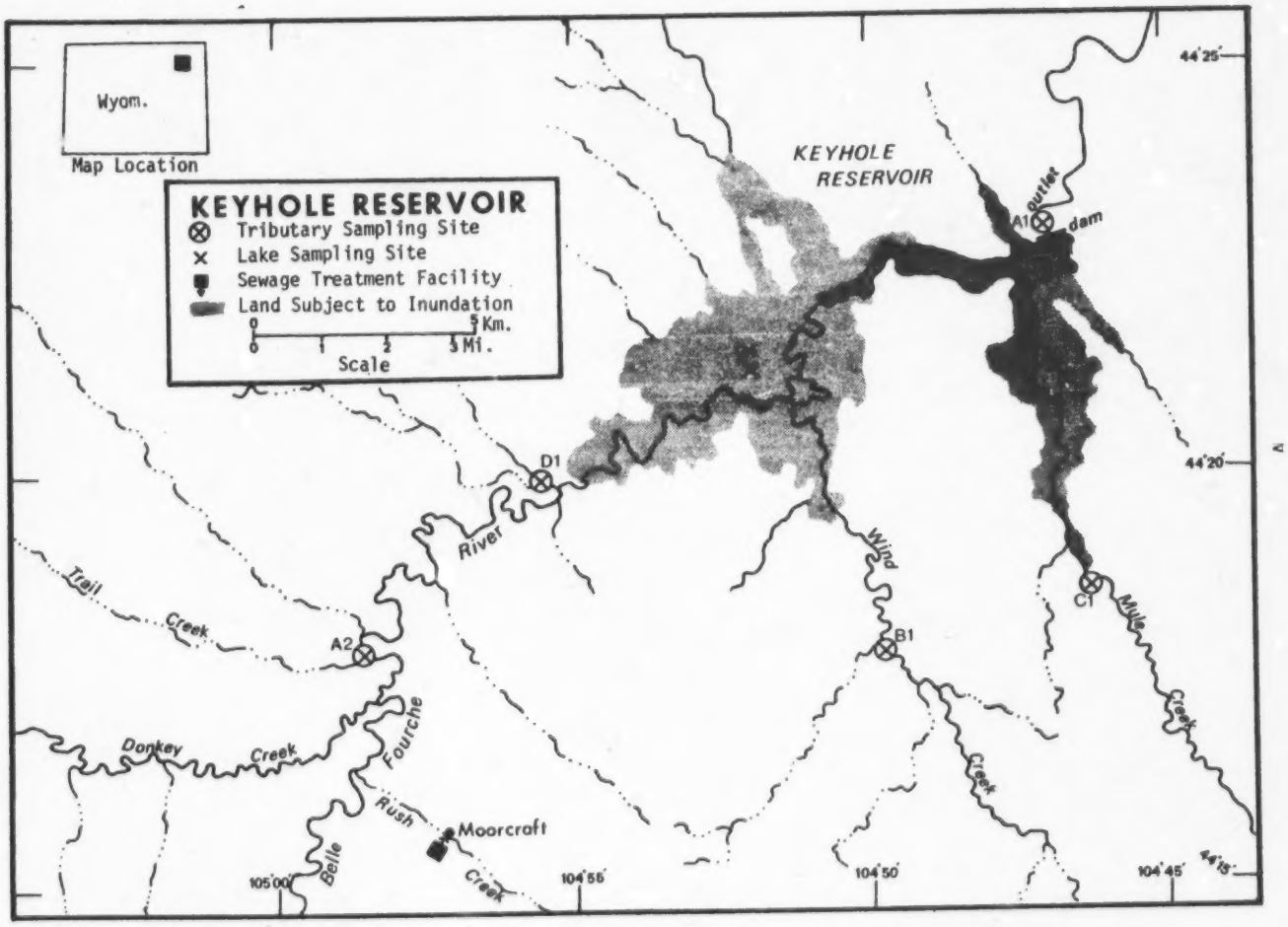
Brigadier General James L. Spence, The Adjutant General of Wyoming, and Project Officer Colonel Donald L. Boyer, who directed the volunteer efforts of the Wyoming National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

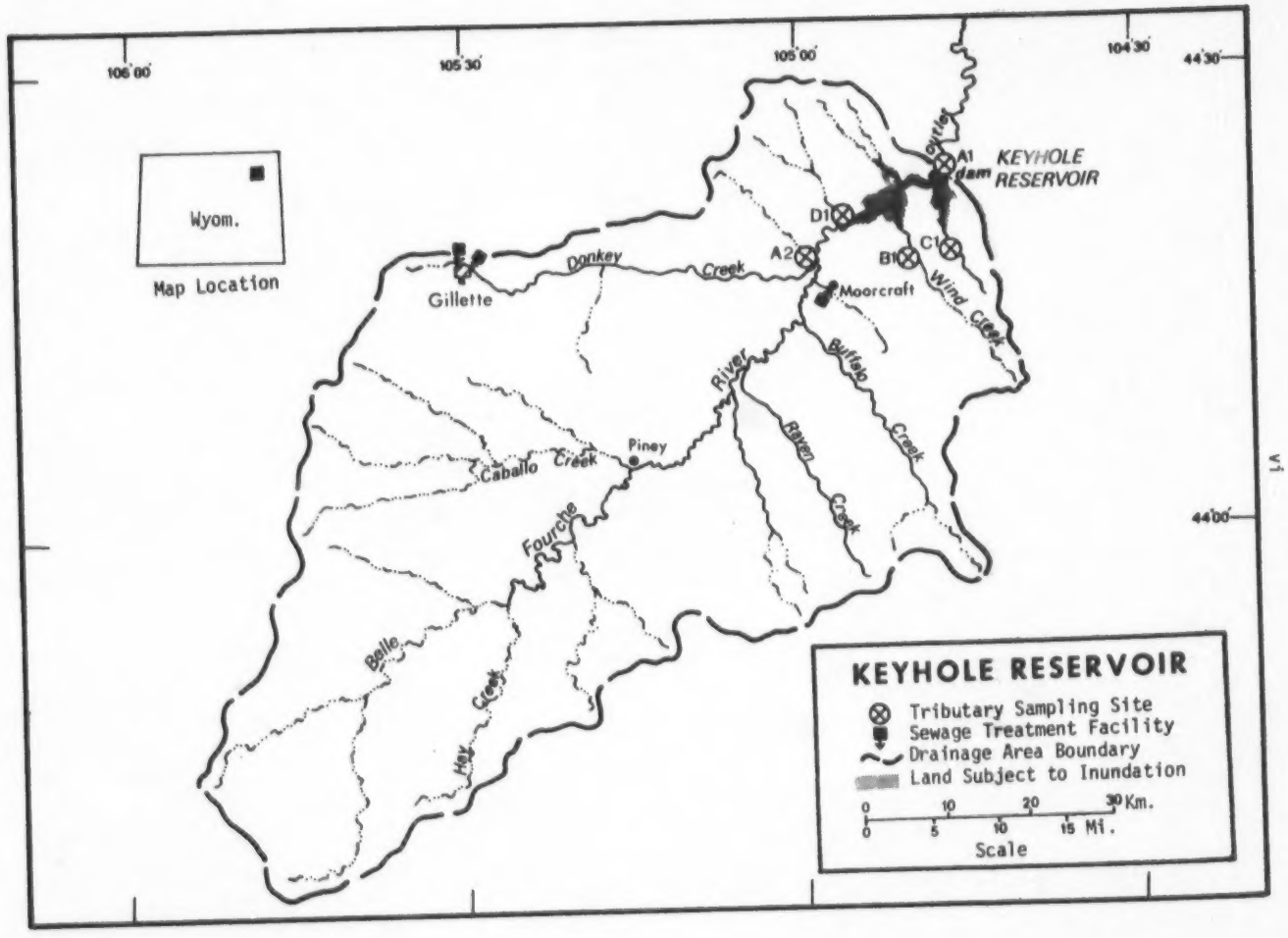
NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

State of Wyoming

NAME	COUNTY
Big Sandy	Sublette, Sweetwater
Boulder	Sublette
Boysen	Fremont
De Smet	Johnson
Flaming Gorge	Sweetwater, WY; Daggett, UT
Fremont	Sublette
Glendo	Converse, Platte
Keyhole	Crook
Ocean	Fremont
Seminoe	Carbon
Soda	Sublette
Viva Naughton	Lincoln
Woodruff Narrows	Uinta
Yellowtail	Bighorn, WY; Bighorn, Carbon, MT


Wyom.
Map Location
KEYHOLE RESERVOIR
Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Land Subject to Inundation
0 1 2 3 Mi.
0 5 Km.
Scale
KEYHOLE RESERVOIR
A1
outlet
dam
D1
River
Wind
Trail
Creek
A2
B1
C1
Mule
Creek
Donkey
Creek
Fourche
Rush
Creek
Belle
Moorcroft
105°00'
104°55'
104°50'
104°45'
44°25'
44°20'
44°15'


106°00'
105°30'
105°00'
104°30'
44°30'
44°00'
Wyom.
Map Location
Gillette
Donkey Creek
Moorcraft
Wind River
Buffalo Creek
Piney
Caballo Creek
Fourche
Belle
Hay Creek
A1
dam
KEYHOLE
RESERVOIR
D1
A2
B1
C1
KEYHOLE RESERVOIR
Tributary Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
Land Subject to Inundation
0 10 20 30 Km.
0 5 10 15 Mi.
Scale

KEYHOLE RESERVOIR

STORET NO. 5608

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Keyhole Reservoir is eutrophic. It ranked eighth in overall trophic quality when the 14 Wyoming lakes and reservoirs sampled in 1975 were compared using a combination of six parameters*. Four of the waterbodies had less median total phosphorus, three had less and one had the same median dissolved orthophosphorus, five had less median inorganic nitrogen, nine had less mean chlorophyll a, and eight had greater mean Secchi disc transparency. Depression of dissolved oxygen with depth occurred at stations 1 and 3 in August.

Survey limnologists noted an algal bloom in the reservoir in October.

B. Rate-Limiting Nutrient:

Due to nutrient changes in the samples from the time of collection to the beginning of the assays, the results are not considered representative of conditions in the reservoir at the times of sampling (05/23/75 and 10/15/75).

The reservoir data indicate nitrogen limitation in May and October and phosphorus limitation in August.

C. Nutrient Controllability:

1. Point sources--The City of Moorcroft contributed 7.2% of the total phosphorus load to Keyhole Reservoir during the

* See Appendix A.

sampling year. The septic tanks serving a lakeshore campground were estimated to have added less than 0.1% of the total load.

The City of Gillette, located approximately 50 km upstream from station A-2, discharged 13,670 kg of total phosphorus into Donkey Creek during the sampling year. However, the impact of this discharge was not evident at station A-2, possibly because of less than normal precipitation and stream flow during the year of sampling. It is probable that the phosphorus load of Gillette impacts Keyhole Reservoir during years of normal precipitation and higher runoff.

The present phosphorus loading of 0.46 $g/m^2/yr$ is more than three times that proposed by Vollenweider (Vollenweider & Dillon, 1974) as a eutrophic loading (see page 11). Because of the high loading and the long hydraulic retention time of the reservoir, all phosphorus inputs should be minimized as much as possible to slow the aging of the reservoir.

2. Non-point sources--Non-point sources, including direct precipitation, contributed 92.8% of the total phosphorus load to the reservoir during the sampling year. The Belle Fourche River added 48.1% of the total; Wind Creek, 29.7%; Mule Creek, 1.3%; and the ungaged tributaries contributed an estimated 9.9%.

The phosphorus export rates of the Belle Fourche River, Wind Creek, and Mule Creek were 2, 22, and 7 $kg/km^2/yr$, respectively (see page 10). The higher rate of Wind Creek may be due to an unknown point source or to insufficient sampling.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS†

A. Morphometry††:

1. Surface area: 38.02 kilometers^2.
2. Mean depth: 6.5 meters.
3. Maximum depth: 51.2 meters.
4. Volume: 246.539 x 10^6 m^3.
5. Mean hydraulic retention time: 15.2 years.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Belle Fourche River	4325.3	0.596
Wind Creek	240.9	0.136
Mule Creek	33.7	0.021
Minor tributaries & immediate drainage -	542.1	0.073
Totals	5142.0	0.826

2. Outlet -

Belle Fourche River	5180.0**	0.514**

C. Precipitation***:

1. Year of sampling: 36.4 centimeters.
2. Mean annual: 44.2 centimeters.

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† Table of metric conversions--Appendix B.
†† Edwards, 1976.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of reservoir; lesser outflow due to evaporation.
*** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Keyhole Reservoir was sampled three times during the open-water season of 1975 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at four stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 15.5 meters at station 1, 10.4 meters at station 2, 14.6 meters at station 3, and 4.6 meters at station 4.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR KEY HOLE RESERVOIR
STORET CODE 5608

PARAMETER	1ST SAMPLING (5/23/75) 4 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (8/29/75) 4 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (10/15/75) 4 SITES RANGE	MEAN	MEDIAN
TEMP (C)	7.7 - 12.1	10.9	11.1	16.6 - 22.7	20.6	20.7	10.6 - 12.1	11.6	11.9
DISS OXY (MG/L)	7.8 - 9.4	8.8	9.0	1.0 - 8.6	6.7	7.4	7.6 - 9.6	8.6	8.5
CNDCTVY (MCHOMO)	566. - 636.	611.	610.	698. - 832.	787.	789.	637. - 690.	667.	665.
PH (STAND UNITS)	8.3 - 8.6	8.5	8.5	8.0 - 8.6	8.5	8.5	8.5 - 8.6	8.5	8.5
TOT ALK (MG/L)	157. - 166.	161.	162.	166. - 177.	171.	172.	167. - 178.	176.	177.
TOT P (MG/L)	0.025 - 0.054	0.042	0.041	0.017 - 0.049	0.027	0.024	0.019 - 0.121	0.033	0.024
ORTHO P (MG/L)	0.003 - 0.012	0.006	0.006	0.002 - 0.012	0.005	0.005	0.002 - 0.008	0.004	0.003
NO2+NO3 (MG/L)	0.020 - 0.070	0.025	0.020	0.020 - 0.110	0.031	0.020	0.020 - 0.020	0.020	0.020
AMMONIA (MG/L)	0.030 - 0.070	0.043	0.040	0.020 - 0.210	0.041	0.020	0.020 - 0.050	0.031	0.030
KJEL N (MG/L)	0.600 - 0.900	0.680	0.700	0.400 - 0.800	0.541	0.500	0.400 - 0.700	0.586	0.600
INORG N (MG/L)	0.050 - 0.140	0.069	0.060	0.040 - 0.320	0.072	0.040	0.040 - 0.070	0.051	0.050
TOTAL N (MG/L)	0.620 - 0.920	0.705	0.720	0.420 - 0.820	0.572	0.540	0.420 - 0.720	0.606	0.620
CHLRPYL A (UG/L)	5.0 - 7.0	6.2	6.4	5.1 - 10.7	7.5	7.2	7.6 - 14.3	9.6	8.3
SECCHI (METERS)	0.6 - 1.7	1.3	1.5	0.3 - 1.2	0.9	1.0	0.9 - 1.5	1.3	1.3

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
05/23/75	1. Asterionella sp.	858
	2. Cryptomonas sp.	775
	3. Chroomonas (?) sp.	719
	4. Ankistrodesmus sp.	83
	5. Stephanodiscus sp.	55
	Other genera	28
	Total	2,518
08/29/75	1. Aphanizomenon sp.	452
	2. Chroomonas (?) sp.	278
	3. Cryptomonas sp.	243
	4. Gomphosphaeria sp.	139
	5. Closterium sp.	35
	Other genera	35
	Total	1,182
10/15/75	1. Aphanizomenon sp.	1,356
	2. Chroomonas (?) sp.	765
	3. Oocystis sp.	417
	4. Cryptomonas sp.	348
	5. Stephanodiscus sp.	104
	Other genera	70
	Total	3,060

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
05/23/75	1	6.3
	2	5.0
	3	7.0
	4	6.6
08/29/75	1	5.1
	2	6.2
	3	8.2
	4	10.7
10/15/75	1	7.6
	2	8.5
	3	8.0
	4	14.3

C. Limiting Nutrient Study:

Due to significant nutrient changes in the samples from the time of collection to the beginning of the assays, the results are not considered representative of conditions in the reservoir at the times the samples were collected (05/23/75 and 10/15/75).

The reservoir data indicate nitrogen limitation in May and October and phosphorus limitation in August. The mean inorganic nitrogen to orthophosphorus ratios were 12 to 1 in May, 14 to 1 in August, and 13 to 1 in October.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Wyoming National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page vi), except for the high runoff month of May when two samples were collected. Sampling was begun in October, 1974, and was completed in June, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Wyoming District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the concentrations in Wind Creek and Mule Creek at stations B-1 and C-1 and the mean annual ZZ flow.

The operators of the Gillette and Moorcroft wastewater treatment plants provided monthly effluent samples and corresponding flow data.

A. Waste Sources*:

1. Known municipal -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Moorcroft	981	stab. pond	250.1	Rush Creek
Gillette	7,200	act. sludge	3,716.6	Donkey Creek

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Belle Fourche River	8,465	48.1
Wind Creek	5,220	29.7
Mule Creek	235	1.3
b. Minor tributaries & immediate drainage (non-point load) -	1,745	9.9
c. Known municipal STP's -		
Moorcraft	1,270	7.2
Gillette	-	-
d. Septic tanks** -	< 5	< 0.1
e. Known industrial - None	-	-
f. Direct precipitation*** -	665	3.8
Total	17,600	100.0

2. Outputs -

Reservoir outlet - Belle Fourche River	210

3. Net annual P accumulation - 17,390 kg.

* Prior, 1974.
** Estimate based on one campground; see Working Paper No. 175.
*** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Belle Fourche River	52,390	45.8
Wind Creek	12,645	11.1
Mule Creek	1,255	1.1
b. Minor tributaries & immediate drainage (non-point load) -	5,400	4.7
c. Known municipal STP's -		
Moorcraft	1,590	1.4
Gillette	-	-
d. Septic tanks* -	70	< 0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	41,045	35.9
Total	114,395	100.0

2. Outputs -

Reservoir outlet - Belle Fourche River	16,840

3. Net annual N accumulation - 97,555 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Wind Creek	22	52
Mule Creek	7	37
Belle Fourche River	2	12

E. Mean Nutrient Concentrations in Ungaged Stream:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Miller Creek	0.284	1.736

* Estimate based on one campground; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.46	0.46	3.0	2.6

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Keyhole Reservoir:	
"Dangerous" (eutrophic loading)	0.14
"Permissible" (oligotrophic loading)	0.07

V. LITERATURE REVIEWED

Edwards, Bryon, 1976. Personal communication (reservoir morphometry). U.S. Bur. of Reclamation, Billings, MT.

Prior, Roy E., 1974. Personal communication (point sources in reservoir drainage). WY Dept. Env. Qual., Cheyenne.

Vollenweider, R. A. and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
5601	BIG SANDY RESERVOIR	0.087	0.060	487.667	4.383	8.800	0.020
5602	BOULDER LAKE	0.008	0.040	361.800	2.483	8.400	0.002
5603	BOYSEN RESERVOIR	0.037	0.140	465.923	6.264	14.400	0.014
5604	LAKE DE SMET	0.033	0.040	409.000	11.167	9.400	0.006
5605	FLAMING GORGE RESERVOIR	0.014	0.605	366.461	5.611	12.200	0.003
5606	FREMONT LAKE	0.006	0.040	-22.000	3.783	7.400	0.002
5607	GLENDO RESERVOIR	0.045	0.315	459.182	8.473	12.600	0.014
5608	KEY HOLE RESERVOIR	0.028	0.050	454.583	7.792	14.000	0.004
5609	OCEAN LAKE	0.043	0.040	478.333	7.500	8.600	0.004
5610	SEMINOLE RESERVOIR	0.030	0.130	447.000	2.536	11.000	0.007
5611	SODA LAKE	0.063	0.040	387.500	5.575	15.000	0.014
5612	VIVA NAUGHTON RESERVOIR	0.065	0.120	430.000	25.067	13.200	0.024
5613	WOODRUFF NARROWS RESERVO	0.069	0.105	470.000	12.950	13.200	0.019
5614	YELLOWTAIL RESERVOIR	0.026	0.310	364.500	5.410	10.000	0.017

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500- MEAN SEC	MEAN CHLORA	15- MIN DO	MEDIAN DISS ORTHO P	INDEX NO
5601	BIG SANDY RESERVOIR	0 (0)	54 (7)	0 (0)	77 (10)	77 (10)	8 (1)	216
5602	BOULDER LAKE	92 (12)	92 (11)	92 (12)	100 (13)	92 (12)	92 (12)	560
5603	BOYSEN RESERVOIR	46 (6)	23 (3)	23 (3)	46 (6)	8 (1)	42 (5)	188
5604	LAKE DE SMET	54 (7)	73 (9)	62 (8)	15 (2)	69 (9)	62 (8)	335
5605	FLAMING GORGE RESERVOIR	85 (11)	0 (0)	77 (10)	54 (7)	46 (6)	85 (11)	347
5606	FREMONT LAKE	100 (13)	73 (9)	100 (13)	85 (11)	100 (13)	100 (13)	558
5607	GLENDO RESERVOIR	31 (4)	8 (1)	31 (4)	23 (3)	38 (5)	42 (5)	173
5608	KEY HOLE RESERVOIR	69 (9)	62 (8)	38 (5)	31 (4)	15 (2)	69 (9)	284
5609	OCEAN LAKE	38 (5)	92 (11)	8 (1)	38 (5)	85 (11)	77 (10)	338
5610	SEMINOLE RESERVOIR	62 (8)	31 (4)	46 (6)	92 (12)	54 (7)	54 (7)	339
5611	SODA LAKE	23 (3)	92 (11)	69 (9)	62 (8)	0 (0)	31 (4)	277
5612	VIVA NAUGHTON RESERVOIR	15 (2)	38 (5)	54 (7)	0 (0)	27 (3)	0 (0)	134
5613	WOODRUFF NARROWS RESERVO	8 (1)	46 (6)	15 (2)	8 (1)	27 (3)	15 (2)	119
5614	YELLOWTAIL RESERVOIR	77 (10)	15 (2)	85 (11)	69 (9)	62 (8)	23 (3)	331

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	5602	BOULDER LAKE	560
2	5606	FREMONT LAKE	558
3	5605	FLAMING GORGE RESERVOIR	347
4	5610	SEMINOLE RESERVOIR	339
5	5609	OCEAN LAKE	338
6	5604	LAKE DE SMET	335
7	5614	YELLOWTAIL RESERVOIR	331
8	5608	KEY HOLE RESERVOIR	284
9	5611	SODA LAKE	277
10	5601	BIG SANDY RESERVOIR	216
11	5603	BOYSEN RESERVOIR	188
12	5607	GLENDO RESERVOIR	173
13	5612	VIVA NAUGHTON RESERVOIR	134
14	5613	WOODRUFF NARROWS RESERVO	119

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR WYOMING 08/05/76

LAKE CODE 5608 KEYHOLE RESERVOIR

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 5180.0

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
5608A1	5180.0	0.034	0.190	0.934	0.566	0.708	0.623	1.189	1.331	0.396	0.071	0.040	0.037	0.514
5608A2	4325.3	0.028	0.396	1.416	0.680	1.303	2.350	0.510	0.283	0.142	0.011	0.008	0.031	0.596
5608B1	240.9	0.0	0.227	0.566	0.227	0.340	0.283	0.0	0.0	0.0	0.0	0.0	0.0	0.136
5608C1	33.7	0.003	0.023	0.023	0.113	0.085	0.0	0.0	0.0	0.0	0.003	0.003	0.003	0.021
5608Z2	569.8	0.0	0.057	0.198	0.085	0.170	0.283	0.057	0.028	0.0	0.0	0.0	0.0	0.073

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 5180.0
SUM OF SUB-DRAINAGE AREAS = 5169.6
TOTAL FLOW IN = 9.93
TOTAL FLOW OUT = 6.12

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
5608A1	10	74	0.085	7	0.085				
	11	74	0.057	6	0.057				
	12	74	0.057	2	0.057				
	1	75	0.057	10	0.057				
	2	75	0.057						
	3	75	0.057	17	0.057				
	4	75	0.057	6	0.057				
	5	75	0.057	1	0.057	15	0.057		
	6	75	0.057	2	0.057				
	7	75	1.472						
	8	75	2.718						
	9	75	0.651						
5608A2	10	74	0.003	7	0.003				
	11	74	0.003	6	0.003				
	12	74	0.003	2	0.003				
	1	75	0.003						
	2	75	0.057						
	3	75	2.549	17	5.663				
	4	75	4.248	6	9.911				
	5	75	2.832	1	4.248	15	0.566		
	6	75	1.133	2	0.425				
	7	75	0.142						
	8	75	0.0						
	9	75	0.0						

TRIBUTARY FLOW INFORMATION FOR WYOMING 08/05/76

LAKE CODE 5608 KEYHOLE RESERVOIR

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
5608B1	10	74	0.0						
	11	74	0.0						
	12	74	0.0						
	1	75	0.0						
	2	75	0.028						
	3	75	0.850	17	3.681				
	4	75	1.133	6	2.832				
	5	75	0.850	1	0.708	15	0.283		
	6	75	0.283						
	7	75	0.028						
	8	75	0.0						
	9	75	0.0						
5608C1	10	74	0.003	7	0.003				
	11	74	0.003	6	0.003				
	12	74	0.003	2	0.003				
	1	75	0.0						
	2	75	0.003						
	3	75	0.003	17	0.003				
	4	75	0.142	6	0.113				
	5	75	0.085	1	0.113	15	0.057		
	6	75	0.057	2	0.003				
	7	75	0.0						
	8	75	0.0						
	9	75	0.0						
5608ZZ	10	74	0.0						
	11	74	0.0						
	12	74	0.0						
	1	75	0.0						
	2	75	0.0						
	3	75	0.283						
	4	75	0.368						
	5	75	0.283						
	6	75	0.227						
	7	75	0.0						
	8	75	0.0						
	9	75	0.0						

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/08/05

560801
44 22 50.0 104 46 30.0 3
KEY HOLE RESERVOIR
56011 WYOMING

090491

11EPALES 2111202
0031 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/05/23	10 30	0000	11.8	9.4	66	628	8.60	160	0.050	0.600	0.030	0.006
	10 30	0005	11.8	9.4		627	8.60	161	0.040	0.700	0.020K	0.007
	10 30	0015	11.6	9.2		625	8.45	161	0.040	0.700	0.020K	0.007
	10 30	0027	10.5	8.4		606	8.45	162	0.040	0.700	0.020	0.005
75/08/29	15 45	0000	22.3	7.6	48	822	8.50	167	0.020	0.500	0.020	0.002
	15 45	0005	21.2	7.6		801	8.50	166	0.020K	0.600	0.020K	0.002K
	15 45	0015	20.9	7.4		788	8.50	169	0.020	0.500	0.020	0.002
	15 45	0030	20.2	5.8		779	8.40	170	0.050	0.500	0.040	0.006
	15 45	0051	16.6	1.0		698	8.00	174	0.210	0.600	0.110	0.012
75/10/15	10 15	0000	12.1	9.0	36	685	8.50	178	0.040	0.500	0.020K	0.002
	10 15	0005	12.0	8.2		672	8.50	177	0.040	0.600	0.020K	0.007
	10 15	0015	12.0	8.3		680	8.50	177	0.040	0.600	0.020K	0.006
	10 15	0036	11.8	8.6		637	8.50	177	0.040	0.600	0.020K	0.003

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/05

560801
44 22 50.0 104 46 30.0 3
KEY HOLE RESERVOIR
56011 WYOMING 090491

11EPALES 2111202
0031 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/05/23	10 30	0000	0.041	6.3	
	10 30	0005	0.050		
	10 30	0015	0.044		
	10 30	0027	0.041		
75/08/29	15 45	0000	0.035	5.1	
	15 45	0005	0.023		
	15 45	0015	0.023		
	15 45	0030	0.017		
	15 45	0051	0.023		
75/10/15	10 15	0000	0.028	7.6	
	10 15	0005	0.029		
	10 15	0015	0.024		
	10 15	0036	0.021		

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STORET RETRIEVAL DATE 76/08/05

S60802
44 21 05.0 104 46 45.0 3
KEY HOLE RESERVOIR
56011 WYOMING
090491

11EPALES 2111202
0038 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/05/23	10 55	0000	0.041	5.0	
	10 55	0005	0.051		
	10 55	0020	0.040		
	10 55	0034	0.045		
75/08/29	16 10	0000	0.020	6.2	
	16 10	0005	0.025		
	16 10	0015	0.024		
	16 10	0031	0.021		
75/10/15	10 40	0000	0.023	8.5	
	10 40	0005	0.019		
	10 40	0015	0.023		
	10 40	0025	0.022		

STORET RETRIEVAL DATE 76/08/05

560802
44 21 05.0 104 46 45.0 3
KEY HOLE RESERVOIR
56011 WYOMING
090491

11EPALES 2111202
0038 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/05/23	10 55	0000	0.041	5.0	
	10 55	0005	0.051		
	10 55	0020	0.040		
	10 55	0034	0.045		
75/08/29	16 10	0000	0.020	6.2	
	16 10	0005	0.025		
	16 10	0015	0.024		
	16 10	0031	0.021		
75/10/15	10 40	0000	0.023	8.5	
	10 40	0005	0.019		
	10 40	0015	0.023		
	10 40	0025	0.022		

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STORET RETRIEVAL DATE 76/08/05

560803
44 22 35.0 104 49 00.0 3
KEY HOLE RESERVOIR
56011 WYOMING

090491

11EPALES 2111202
0047 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/05/23	11	15 0000	11.4	9.0	60	610	8.60	158	0.040	0.600	0.020K	0.007
	11	15 0005	11.4	9.4		610	8.60	157	0.040	0.600	0.020K	0.007
	11	15 0015	11.0	8.2		614	8.40	162	0.060	0.700	0.020	0.006
	11	15 0030	9.8	7.8		594	8.30	163	0.070	0.600	0.040	0.012
	11	15 0043	7.7	7.8		566	8.30	166	0.070	0.600	0.070	0.005
75/08/29	17	20 0000	21.9	7.8	36	812	8.60	175	0.020	0.400	0.020	0.003
	17	20 0005	21.1	8.0		793	8.60	177	0.020	0.400	0.020	0.002
	17	20 0015	20.7	7.0		789	8.50	177	0.020	0.500	0.030	0.002
	17	20 0030	20.1	6.0		774	8.40	166	0.050	0.500	0.050	0.002
	17	20 0048	19.0	4.0		755	8.20	167	0.120	0.600	0.060	0.009
75/10/15	10	00 0000	12.0	7.6	45	668	8.50	175	0.030	0.400	0.020K	0.003
	10	00 0005	12.0	8.4		685	8.55	176	0.030	0.600	0.020K	0.003
	10	00 0015	12.0	8.2		688	8.60	177	0.040	0.600	0.020K	0.006
	10	00 0046	12.0	8.0		690	8.50	177	0.050	0.700	0.020K	0.008

K VALUE KNOWN TO BE
LESS THAN INDICATED

27

STORET RETRIEVAL DATE 76/08/05

560803
44 22 35.0 104 49 00.0 3
KEY HOLE RESERVOIR
56011 WYOMING
090491

11EPALES 2111202
0047 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCOT LT REMNING PERCENT
75/05/23	11	15 0000	0.039	7.0	
	11	15 0005	0.054		
	11	15 0015	0.042		
	11	15 0030	0.031		
	11	15 0043	0.025		
75/08/29	17	20 0000	0.025	8.2	
	17	20 0005	0.025		
	17	20 0015	0.026		
	17	20 0030	0.022		
	17	20 0048	0.041		
75/10/15	10	00 0000	0.032	8.0	
	10	00 0005	0.022		
	10	00 0015	0.025		
	10	00 0046	0.121		

STORET RETRIEVAL DATE 76/08/05

560804
44 21 15.0 104 51 58.0 3
KEY HOLE RESERVOIR
56011 WYOMING

090491

11EPALES 2111202
0011 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
75/05/23	11 35	0000	11.1	8.4	22	601	8.55	157	0.040	0.900	0.020K	0.003
	11 35	0007	11.1	8.4		600	8.55	157	0.030	0.700	0.020K	0.004
75/08/29	18 30	0000	22.7	6.5	12	832	8.60	173	0.020	0.800	0.020K	0.006
	18 30	0005	20.6	8.6		792	8.65	174	0.020K	0.600	0.020	0.005
	18 30	0015	20.0	7.6		783	8.60	173	0.020K	0.600	0.020	0.004
75/10/15	09 45	0000	10.7	8.0	60	647	8.60	174	0.020K	0.600	0.020	0.002
	09 45	0005	10.6	9.0		647	8.60	177	0.020K	0.600	0.020K	0.003

K VALUE KNOWN TO BE
LESS THAN INDICATED

24

STORET RETRIEVAL DATE 76/08/05

560K04
44 21 15.0 104 51 58.0 3
KEY HOLE RESERVOIR
56011 WYOMING
090491

11EPALES 2111202
0011 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
75/05/23	11 35	0000	0.039	6.6	
	11 35	0007	0.043		
75/08/29	18 30	0000	0.040	10.7	
	18 30	0005	0.049		
	18 30	0015	0.023		
75/10/15	09 45	0000	0.042	14.3	
	09 45	0005	0.028		

APPENDIX E

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

STORET RETRIEVAL DATE 76/08/05

5608A1
44 23 05.0 104 46 50.0 4
BELLE FOURCHE RIVER
56 15 MOORCROFT
O/KEYHOLE RESERVOIR 090491
BELOW KEYHOLE DAM 12 MI NE OF MOORCROFT
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/07	13 00		0.080	0.800	0.270	0.005K	0.010
74/11/06	12 45		0.032	1.100	0.500	0.005K	0.010
74/12/02	13 30		0.016	0.900	0.280	0.005K	0.020
75/01/10	11 20		0.012	0.600	0.104	0.005K	0.010
75/03/17	13 50		0.035	1.050	0.300	0.005K	0.010
75/04/06	10 50		0.040	1.750	0.440	0.005K	0.030
75/05/01	08 25		0.040	1.300	0.470	0.005	0.010
75/05/15	13 00		0.025	0.600	0.320	0.005K	0.010K
75/06/02	10 15		0.025	0.950	0.280	0.005	0.010

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/08/05

560842
44 17 45.0 104 58 30.0 4
BELLE FOURCHE RIVER
56 15 MOORCROFT
T/KEYHOLE RESERVOIR 090491
BNK 100 FT E OF D RD 2 MI NW MOORCROFT
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/07	10 40		0.016	1.600	0.090	0.005	0.047
74/11/06	15 40		0.184	3.000	0.045	0.055	1.350
74/12/02	15 10		0.048	2.700	0.630	0.960	1.250
75/03/17	15 30		0.135	2.300	0.325	0.123	0.540
75/04/06	13 00		0.200	7.400	0.183	0.022	0.250
75/05/01	10 30		0.025	1.900	0.340	0.075	0.280
75/05/15	15 00		0.065	1.200	0.050	0.050	0.190
75/06/02	11 55		0.005	2.200	0.050	0.040	0.240

STORET RETRIEVAL DATE 76/06/05

560881
44 17 50.0 104 49 45.0 4
#IND CREEK
56 15 MOORCROFT
T/KEYHOLE RESERVOIR 090491
BNK 100 FT E OF RD 6 MI NE OF MOORCROFT
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/11/06	14 10		0.480	3.100	0.185	0.050	1.300
75/03/17	14 35		0.210	3.750	0.165	0.115	2.400
75/04/06	12 00		0.260	2.500	0.065	0.065	1.250
75/05/01	09 28		0.650	3.300	0.175	0.573	1.800
75/05/15	13 50		0.280	2.000	0.130	0.035	0.400
75/06/02	16 00		0.010	1.150	0.025	0.020	0.150

STORET RETRIEVAL DATE 76/08/05

5608C1
44 19 22.0 104 46 30.0 4
MULE CREEK
56 15 MOORCROFT
T/KEYHOLE RESERVOIR 090491
OLD SUNDANCE RD BRDG 11.5 MI NE MOORCRFT
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/07	12 35		0.016	1.300	0.025	0.005	0.035
74/11/06	13 50		0.448	1.200	0.200	0.025	0.205
74/12/02	13 45		0.010	0.700	0.024	0.010	0.040
75/03/17	14 15		0.230	2.500	0.155	0.220	1.100
75/04/06	11 25		0.210	2.100	0.060	0.125	1.050
75/05/01	09 00		0.970	2.900	0.095	0.050	0.086
75/05/15	13 20		0.390	1.200	0.050	0.025	0.300
75/06/02	10 40		0.010	0.950	0.030	0.010	0.050

STORET RETRIEVAL DATE 76/08/05

5608D1
44 20 20.0 104 55 50.0 4
MILLER CREEK
56 15 MOORCROFT
T/KEYHOLE RESERVOIR 090491
DIRT RD BRDG 5.5 MI N OF MOORCROFT
11EPALES 2111204
0000 FEE: DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
75/03/17	14	50	0.090	1.850	0.095	0.320	0.630
75/04/06	12	30	0.050	2.300	0.075	0.150	0.310
75/05/01	09	45	0.015	1.600	0.115	0.125	0.230
75/05/15	14	10	0.015	1.150	0.075	0.075	0.150
75/06/02	11	20	0.010	1.600	0.195	0.030	0.100

STORET RETRIEVAL DATE 76/08/05

5608XA AS5608XA P007200
44 16 30.0 105 25 00.0 4
GILLETTE
56 CAMPBELL CO.
T/KEYHOLE RES. 090292
DONKEY CREEK
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
75/02/10	09 00								
CP(T)-			3.160	2.940	0.100	6.400	7.425	0.900	0.900
75/02/10	16 00								
75/03/31	00 00								
CP(T)-			0.617	14.000	2.700	5.500	7.400	0.800	0.800
75/03/31	08 00								
75/05/01	09 00								
CP(T)-			0.400	21.000	2.900	6.100	6.100	0.900	0.900
75/05/01	17 00								
75/05/21	09 00								
CP(T)-			4.100	7.500	0.081	6.800	9.100	0.900	0.900
75/05/21	17 00								
75/06/11	09 00								
CP(T)-			2.200	8.400	2.400	7.250	9.900	1.000	1.000
75/06/11	15 00								
75/07/08	14 30		0.025	6.100	1.150	4.400	13.800	0.900	0.900
75/07/30	08 00								
CP(T)-			3.800	11.000	0.130	9.400	9.400	1.000	1.000
75/07/30	16 00								
75/08/20			0.775	9.300	0.031	6.400	9.500		
75/09/16	09 30		3.800	9.000	0.110	5.100	10.500	1.200	1.200
75/10/15			5.800	8.700	0.225	12.600	14.500	1.200	1.200
75/11/12	14 00		8.400	4.700	0.175	10.500	11.000	1.000	1.000
75/12/23			0.500	15.000	4.400	8.300	10.000	1.000	1.000

STORET RETRIEVAL DATE 76/08/05

5608YA PD5608YA P000981
44 15 30.0 104 57 00.0 4
MOORCROFT
56 ROOK CO.
T/KEYHOLE RES.
RUSH CREEK 090491
11EPALES 2141204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
75/02/03	15 30		0.080	40.000	27.000	14.500	15.000	0.086	0.086
75/03/03	15 30		0.400	6.800	0.080		9.800	0.086	0.086
75/04/07	13 30		0.050	2.600	1.040		13.300	0.086	0.073
75/04/28	13 00		0.050	33.000	22.000	12.000	13.300	0.086	0.086
75/05/19	15 00		0.200	4.400	24.000	10.530	11.500	0.072	0.072
75/06/23	11 00		0.050	11.000	9.600	13.000	13.500	0.086	0.026
75/07/22	15 00		3.000	5.800	0.073	13.500	14.400	0.043	0.043
75/08/26	10 00			4.500				0.043	0.043
75/09/09	07 00			16.000			23.000	0.036	0.036
75/10/05	16 00		3.700		3.200	2.700		0.029	0.035
75/11/17	14 30		9.100	9.400	0.100K	14.000	16.500	0.086	0.086

K VALUE KNOWN TO BE
LESS THAN INDICATED

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO. PB277051
4. TITLE AND SUBTITLE Report on Keyhole Reservoir, Crook County, Wyoming		5. REPORT DATE Prepared August 1977 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Anonymous (National Eutrophication Survey Staff)		8. PERFORMING ORGANIZATION REPORT NO. Working Paper # 888
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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

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